Claims

We claim:

1. An apparatus for magnetically stirring a flowable material , comprising:

a mixing vessel for containing a flowable material;

a flowable material contained in the mixing vessel; and

at least one magnetic field generator positioned around the mixing vessel and adapted to produce a magnetic field having a circumferential component and a longitudinal component;

wherein actuation of the magnetic field generator produces a spiral resultant stirring force on the flowable material; and

wherein the stirring force is sufficient to cause the flowable material to circulate throughout the mixing vessel at a predetermined rate of circulation.

2. The apparatus of claim 1 wherein the flowable material is a molten metallic alloy.

3. The apparatus of claim 2 wherein the metallic alloy is an aluminum alloy.

4. The apparatus of claim 1 wherein the flowable material is a molten alloy having a solid particulate phase suspended in a liquid phase.

5. The apparatus of claim 1 wherein the magnetic field generator further includes a first stator adapted to produce a circumferential magnetomotive force and a second stator adapted to produce a longitudinal magnetomotive force.

6. The apparatus of claim 1 further including a power source operationally connected to the at least one magnetic field generator and an electronic controller operationally connected to the power source, wherein the electronic controller is adapted monitor the voltage output of the power source and provide a control signal thereto to adjust the power supplied in response to a predetermined relationship between the voltage output of the power supply and the power output required to maintain the circulation of the flowable material at the predetermined rate of circulation.

7. The apparatus of claim 1 further including a power source operationally connected to the at least one magnetic field generator and an electronic controller operationally connected to the power source, wherein the electronic controller is adapted to monitor the temperature of the flowable material and provide a control signal to the power source to adjust the power supplied in response to a predetermined relationship between the temperature of the molten material and the power required to maintain the circulation of the flowable material at the predetermined rate of circulation.

8. An apparatus for magnetomotively stirring a metal melt, comprising:

a mixing vessel;

a metal melt having a variable viscosity and at least partially filling the mixing vessel;

means for generating a magnetomotive force field of sufficient strength to stir the metal melt and having a nonzero circumferential component and a nonzero longitudinal component defining a stirring force; and

means for controlling the stirring force such that the metal melt is stirred as a function of the variable viscosity;

wherein the melt is stirred increasingly slowly as the variable viscosity increases.

9. The apparatus of claim 8 wherein the magnetomotive force field defines a substantially cylindrical mixing volume having a central axis extending therethrough.

10. The apparatus of claim 9 wherein the means for generating a magnetomotive force field include at least one stator for producing a circumferential magnetic field oriented substantially perpendicular to the central axis and at least one stator for producing a substantially longitudinal magnetic field oriented substantially parallel to the central axis.

11. The apparatus of claim 8 wherein the metal melt is an alloy having a first solid particulate phase suspended in a second liquid phase.

12. The apparatus of claim 11 wherein the alloy contains aluminum.

13. The apparatus of claim 11 wherein the first solid particulate phase is non-metallic.

14. A magnetomotive stirring apparatus, comprising:

a stator array for providing a resultant magnetomotive force, including:

a first stator adapted to produce a first magnetomotive force;

a second stator adapted to produce a second magnetomotive force; and

a third stator adapted to produce a third magnetomotive force; and

an electronic controller operationally connected to the stator array and adapted to control the resultant magnetomotive force;

wherein the first stator, the second stator, and the third stator are stacked to define a substantially cylindrical region for substantially containing magnetomotive forces; and

wherein the second stator is between the first stator and the third stator.

15. The magnetomotive stirring apparatus of claim 14 wherein the first and the third magnetomotive force are circumferential relative the cylindrical region and wherein the second magnetomotive force is longitudinal relative the cylindrical region.

16. The magnetomotive stirring apparatus of claim 14 further including a mixing vessel positioned in the substantially cylindrical region for substantially containing the resultant magnetomotive force.

17. The magnetomotive stirring apparatus of claim 16 wherein the mixing vessel is substantially electrically insulating and is substantially resistant to attack from molten metals.

18. The magnetomotive stirring apparatus of claim 14 further including:

a power supply adapted to produce a power output having a variable output voltage electrically connected between the stator array and the electronic controller;

wherein the electronic controller is adapted to measure the output voltage of the power supply; and

wherein the electronic controller controls the power output of the power supply as a function of the output voltage.

19. The magnetomotive stirring apparatus of claim 14 further including:

a power supply adapted to produce a power output having a variable output voltage electrically connected between the stator array and the electronic controller;

wherein the electronic controller is adapted to measure the temperature in the mixing vessel; and

wherein the electronic controller controls the power output of the power supply as a function of the temperature in the mixing vessel.

20. A magnetomotive stirring assembly comprising;

a stator assembly adapted to produce a magnetomotive force field and defining a generally cylindrical magnetomotive stirring volume having a central axis extending substantially perpendicularly through the generally cylindrical magnetomotive stirring volume and having a generally cylindrical core portion and a generally cylindrical radial portion surrounding the generally cylindrical core portion;

wherein actuation of the stator assembly produces a magnetomotive force field having a volume dependent circumferential component and a volume dependent axial component that combine to produce a resultant magnetomotive force throughout the magnetomotive stirring volume;

wherein the volume dependent axial component produces an axial magnetomotive force in the generally cylindrical radial portion directed substantially parallel to the central axis in a first axial direction;

wherein the strength of the axial magnetomotive force increases with radial distance from the central axis throughout the mixing volume;

wherein the volume dependent circumferential component produces a circumferential magnetomotive force in the generally cylindrical radial portion directed tangentially to a cylindrical section taken therethrough perpendicular to the central axis;

wherein the strength of the circumferential magnetomotive force increases with radial distance from the central axis throughout the mixing volume; and

wherein the resultant magnetomotive force spirals in the first axial direction through the generally cylindrical radial portion.

21. The magnetomotive stirring assembly of claim 20 further including a volume of electrically conductive flowable material confined in the generally cylindrical magnetomotive stirring volume, wherein the volume of electrically conductive flowable material has a generally cylindrical inner portion occupying the generally cylindrical core portion of the magnetomotive stirring volume and a generally cylindrical outer portion occupying the generally cylindrical radial portion of the magnetomotive stirring volume, wherein the resultant magnetomotive force urges the electrically conductive flowable material into motion, wherein the generally cylindrical outer portion flows spirally in the first axial direction, and wherein the generally cylindrical inner portion flows in a second, opposite direction.

22. A method for magnetically stirring a flowable metallic composition to quickly and efficiently facilitate heat transfer therewith, comprising the steps of:

a) providing a flowable metallic composition responsive to a magnetomotive force;

b) applying a magnetomotive force having non-zero rotational and linear components; and

c) circulating the flowable metallic composition to substantially equilibrate the temperature thereof.

23. The method of claim 22 wherein the metallic composition is thixotropic and further including the step of:

d) after b) and before c), generating sufficient shear forces in the thixotropic flowable metallic composition to cause thixotropic flow.

24. The method of claim 22 further including the steps of:

e) after a) and before b), growing dendritic particles in the flowable metallic composition; and

f) after b), circulating the flowable metallic composition to degenerate dendrites to produce a flowable metallic composition substantially comprising rounded primary particles.

25. A method for stirring a flowable metallic composition, comprising the steps of:

a) providing a flowable metallic composition having a solid substantially dendritic particulate phase and a liquid metallic phase and responsive to a magnetomotive force;

b) applying a magnetomotive shearing force sufficient to induce the flowable metallic composition to flow; and

c) circulating the flowable metallic composition to substantially degenerate the solid substantially dendritic particulate phase to form a solid substantially rounded particulate phase.

26. An apparatus for magnetically stirring a flowable metallic composition, comprising:

a mixing vessel for containing a flowable metallic composition;

a flowable metallic composition contained in the mixing vessel; and

at least one magnetic field generator positioned around the mixing vessel and adapted to produce a magnetic field having a rotational component and a linear component;

wherein actuation of the magnetic field generator produces a magnetomotive stirring force having a predetermined pattern and acting on the flowable metallic composition; and

wherein the magnetomotive stirring force is sufficient to cause the flowable metallic composition to circulate throughout the mixing vessel in a predetermined pattern.

27. A magnetomotive stirring apparatus, comprising;

a stator array for providing a resultant magnetomotive force, including:

a first stator adapted to produce a linear magnetomotive force;

a second stator adapted to produce a rotational magnetomotive force; and

a third stator adapted to produce a linear magnetomotive force; and

an electronic controller operationally connected to the stator array and adapted to control the resultant magnetomotive force;

wherein the first stator, the second stator, and the third stator are stacked to define a substantially cylindrical region for substantially containing magnetomotive forces; and

wherein the second stator is between the first stator and the third stator.

28. The magnetomotive stirring apparatus of claim 27 further including a mixing vessel positioned in the substantially cylindrical region substantially for containing magnetomotive forces.

29. The magnetomotive stirring apparatus of claim 28 wherein the mixing vessel is substantially electrically insulating and is substantially resistant to attack from molten metals.

30. The magnetomotive stirring apparatus of claim 27 further including;

a power supply adapted to produce a power output having a variable output voltage is connected between the stator array and the electronic controller;

wherein the electronic controller is adapted to measure the output voltage of the power supply; and

wherein the electronic controller controls the power output of the power supply as a function of the output voltage.